

# **SEMICONDUCTOR MEMORY DEVICE WITH ADJUSTABLE I/O BANDWIDTH**

## **BACKGROUND OF THE INVENTION**

### **5 1. Field of the Invention**

The present invention generally relates to a semiconductor memory device, and more specifically, to a semiconductor memory device compatible with various systems having different kinds of data input/output (I/O) bandwidths.

### **2. Description of the Prior Art**

10 A conventional memory device has a fixed I/O bandwidth. A system using a memory device may have different bandwidths depending on manufacturing companies or its usage. Therefore, the conventional memory device requires an additional interfacing device to be used in a system having different data bandwidth from that of the conventional memory device.

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## **SUMMARY OF THE INVENTION**

It is therefore an object of the present invention to provide a memory device configured to control a bandwidth of I/O data.

20 According to an embodiment of the present invention there is provided a memory device, including: a plurality of data I/O buffers connected one by one to a plurality of I/O ports; a switch array including a plurality of switches for connecting the plurality of data I/O buffers to a plurality of sense amplifier arrays; and a switch controller for receiving an external control signal to control the data I/O buffers and the

plurality of switches.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a block diagram illustrating a structure of a memory device according to a preferred embodiment of the present invention.

5 Fig. 2 is a structural diagram illustrating a main bitline pull-up controller, a cell array block, and a column selection controller of Fig. 1.

Fig. 3 is a structural diagram illustrating the main bitline pull-up controller of Fig. 2.

Fig. 4 is a structural diagram illustrating a main bitline load controller of Fig. 2.

10 Fig. 5 is a structural diagram illustrating a column selection controller of Fig. 2.

Fig. 6 is a detailed structural diagram illustrating a sub cell block of Fig. 2.

Figs. 7a and 7b are timing diagrams illustrating read/write operations of the sub cell block of Fig. 6.

15 Figs. 8a through 8d are structural diagrams illustrating a data I/O buffer and a data pad of Fig. 1.

Figs. 9a through 9b are structural diagrams illustrating a switch array, a data I/O buffer and a sense amplifier array of Fig. 1.

Fig. 10 is a structural diagram illustrating the switch array of Fig. 9.

Fig. 11 is a structural diagram illustrating the sense amplifier array and a column decoder of Fig. 1.

Figs. 12a through 12b are detailed structural diagrams of a switch controller of  
5 Fig. 1.

Figs. 13a through 13d are timing diagrams illustrating operations of the switch array, the sense amplifier array and the data I/O buffer of Fig. 1.

## **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The present invention will be described in more detail with reference to the  
10 accompanying drawings.

Fig. 1 is a block diagram illustrating a structure of a memory device which can control an I/O bandwidth according to a preferred embodiment of the present invention. The memory device of the present invention comprises a cell array block 100, a main bitline pull-up controller 11 for pulling up a main bitline included in the cell array block  
15 100 to a positive voltage, a column selection controller 12 for connecting the main bitline to a data bus 20, a sense amplifier array 30 connected to the data bus 20, a switch array 400 for controlling the sense amplifier array, and a data I/O buffer 500 for exchanging data with the sense amplifier array 30. Additionally, the memory device of the present invention comprises a column decoder 200 for controlling the switch array  
20 400, and a switch controller 300 for controlling the switch array 400 and the data I/O buffer 500. The memory device further comprises I/O ports or data pads 600

connected to the data I/O buffer 500 for inputting and outputting a plurality of data bits (data signals are referred to herein as "data bits").

Fig. 2 is a structural diagram illustrating a cell array block 100 of Fig. 1. The cell array block 100 comprises one or a plurality of main bitline load controllers 13 and  
5 a plurality of sub cell blocks 110.

Fig. 3 is a structural diagram illustrating the main bitline pull-up controller 11 of Fig. 2. The main bitline pull-up controller 11 comprises a PMOS transistor having a gate to receive a control signal MBPUC, a source connected to a power source VPP(VCC) and a drain connected to a main bitline MBL.

10 The main bitline pull-up controller 11 pulls up the main bitline MBL to a voltage VPP(VCC) in a precharge operation.

Fig. 4 is a structural diagram illustrating the main bitline load controller 13 of Fig. 2. The main bitline load controller 13 comprises a PMOS transistor having a gate to receive a control signal MBLC, a source connected to a power source VPP(VCC) and  
15 a drain connected to the main bitline MBL.

The main bitline load controller 13, as a resistant device connected between the power source VPP(VCC) and the main bitline MBL, determines a potential of the main bitline according to the amount of current flowing through the main bitline load controller 13 in data sensing action.

20 One or more of the main bitline load controllers 13 are connected to one main

bitline MBL. When two or more main bitline load controllers 13 are connected to one main bitline, the same number of sub cell blocks 110 are assigned to a main bitline load controller 13 and the main bitline load controllers 13 are evenly placed apart from each other.

5 Fig. 5 is a structural diagram illustrating the column selection controller 12 of Fig. 2. The column selection controller 12 is a switch for connecting the main bitline MBL to a data bus. On/off operations of the column selection controller 12 are controlled by control signals CSN and CSP.

Fig. 6 is a detailed structural diagram illustrating the sub cell block 110 of Fig.

10 2.

The sub cell block 110 comprises a sub bitline SBL, and NMOS transistors N1, N2, N3, N4 and N5. The sub bitline SBL is connected in common to a plurality of unit cells, each of which is connected to a wordline WL<m> and a plateline PL<m>. The NMOS transistor N1 for regulating a current has a gate connected to a first terminal of  
15 the sub bitline SBL, and a drain connected to the main bitline MBL. The NMOS transistor N2 has a gate connected to a control signal MBSW, a drain connected to a source of the NMOS transistor N1 and a source connected to a ground. The NMOS transistor N3 has a gate connected to a control signal SBPD, a drain connected to a second terminal of the sub bitline SBL and a source connected to a ground. The  
20 NMOS transistor N4 has a gate connected to a control signal SBSW2, a source connected to the second terminal of the sub bitline SBL and a drain connected to a control signal SBPU. The NMOS transistor N5 has a gate connected to a control

signal SBSW1, a drain connected to the main bitline MBL and a source connected to the second terminal of the sub bitline SBL.

When a unit cell is to be accessed, only the sub bitline connecting the unit cell is connected to the main bitline. Here, the sub bitline SBL is connected to the main bitline MBL by the NMOS transistor N5. Accordingly, memory read/write operations  
5 can be performed even with a smaller amount of load corresponding to one sub bitline rather than a larger amount of load corresponding to the whole bitline.

A potential of the sub bitline SBL is grounded when the control signal SBPD is activated. The control signal SBPU regulates a voltage to be provided to the sub  
10 bitline SBL. The control signal SBSW1 regulates the flow of a signal between the sub bitline SBL and the main bitline MBL. The control signal SBSW2 regulates the flow of a signal between the control signal SBPU and the sub bitline SBL.

The sub bitline SBL connected to a gate of the NMOS transistor N1 regulates a sensing voltage of the main bitline. The main bitline MBL is connected to the power  
15 source VPP(VCC) via the main bitline load controller 13 (see Fig. 4). When a control signal MBSW becomes “high”, current flows from the power source VPP(VCC), through the main bitline load controller 13, the main bitline MBL and the NMOS transistors N1 and N2, to a ground. Here, the amount of the current is determined by a voltage of the sub bitline SBL connected to the gate of the NMOS transistor N1. If  
20 data of a cell is “1”, the amount of the current becomes larger, thereby decreasing the voltage of the main bitline MBL. If data of a cell is “0”, the amount of the current becomes smaller, thereby increasing the voltage of the main bitline MBL. Here, the

cell data can be detected by comparing the voltage of the main bitline MBL with a reference voltage. Detecting the cell data is performed in the sense amplifier array 30.

Fig. 7a is a timing diagram illustrating a write operation of the sub cell block of Fig. 6.

5        If an address transits in t1, a chip starts a writing operation according to an address transition detection signal ATD.

In t2 and t3, data of a cell is detected by activating a wordline WL and a plateline PL. When data of the cell is “high”, the voltage of the sub bitline rises, and current flowing through the NMOS transistor N1 becomes larger. As a result, the  
10        voltage of the main bitline MBL becomes lower than a reference level. On the other hand, if data of the cell is “low”, the voltage of the sub bitline SBL falls, and current flowing through the NMOS transistor N1 becomes smaller. As a result, the voltage of the main bitline MBL becomes higher than a reference level.

In t4, a self-boosting operation is prepared by setting the control signal SBSW2  
15        at a “high” level. In t5, “high” level data is written into the cell. If the control signal SBSW2 is “high”, the control signal SBSW2, the wordline WL and the sub bitline SBL are driven to “high” levels when the control signal SBPU becomes “high”. Voltages of these signals rise higher than the voltage VPP by the self-boosting operation. In t5, since the wordline WL and the bitline SBL are high, and the plateline PL is low, data  
20        “1” is automatically written into the cell.

In t6, “low” level data is written. If the control signals SBPD and SBSW2 are

inactivated, and the control signal SBSW1 is activated, data “0” provided from the main bitline MBL is supplied to the sub bitline SBL. Here, since the voltage of the plateline PL is “high”, data “0” is written into the cell. If a signal provided from the bitline is “1”, the voltage of the plateline is “high”, and the voltage of the sub bitline SBL is also “high”. As a result, data “1” written in t5 is maintained without change.

In order to improve a sensing margin by stabilizing an initial state of a cell storage node, the wordline WL is activated earlier than the plateline. Then, the wordline WL is activated in t2, and then the plateline PL in t3. In t2, the control signal SBPD is maintained at the “high” level, the data of the cell is initialized as “0”. After initialization, the control signal SBPD is inactivated to the “low” state, and the plateline is activated to the “high” level. After the data “0” is written in t6, the wordline WL is inactivated earlier than the plateline PL by inactivating the wordline WL in t7, and then the plateline PL in t8 (not shown).

Fig. 7b is a timing diagram illustrating a read operation of the sub cell block of Fig. 6.

The operations in the intervals t2 through t6 are as described in Fig. 7a. The read operation is different in that data detected in a sense amplifier (not shown) is not externally outputted.

In t5 and t6, a restore operation is performed. In the restore operation, the data detected in the sense amplifier (not shown) is temporarily stored, and then re-written into the cell. Since the data stored in the sense amplifier is provided to the cell



through the bitline, the restore operation is similar to the write operation. In t5, the data “1” is automatically written in the same manner of the write operation. In t6, the data “1” written in the section t5 is maintained if the data “1” is provided to the bitline, and the data “0” is written if the data “0” is provided to the bitline.

5           Figs. 8a through 8d are structural diagrams illustrating a data I/O buffer and a data pad of Fig. 1.

Referring to Fig. 8a, data pads 610 and 620 comprise DQ\_0 through DQ\_15. The data pads 610 and 620 are connected to a data I/O buffer 500 (see Fig. 1). The data I/O buffer 500 is divided into a lower byte region 510 and an upper byte region 520. 10 DQ\_0 through DQ\_7 are connected to the lower byte region 510, and DQ8 through DQ15 are connected to the upper byte region 520. DQ\_15 in the upper byte is used as an A\_LSB signal which is provided to the switch controller 300 (see Fig. 1). The A\_LSB signal corresponds to an additional address signal. For example, when a system bus processes data by 1 byte, and a memory device processes data by 2 bytes, 15 data of 2 bytes should be stored in a memory address for efficiency of the memory device. However, since the system processes data in 1 byte, 2 bytes should be differentiated and then processed by the memory device. Here, by using the control signal A\_LSB, data inputted/outputted to and from the memory device can be processed by 1 byte.

20           Fig. 8b has the same structure as Fig. 8a. However, it is different in that the A\_LSB signal is provided from one of the bits DQ\_8 through DQ\_14 included the upper byte except the most significant bit DQ\_15.

A preferred embodiment shown in Fig. 8c comprises a plurality of upper byte regions unlike the preferred embodiments shown in Figs. 8a and 8b. A control signal which is one of  $A_0\_LSB$ , ...,  $A_n\_LSB$ , exists in each of the upper byte regions. These signals are outputted from the most significant bit in each upper byte region. The control signals  $A_0\_LSB$  through  $A_n\_LSB$  are used as additional address signals like the control signal  $A\_LSB$  of Fig. 8a.

Fig. 8d has the same structure of Fig. 8c. However, it is different in that the control signals  $A_0\_LSB$  through  $A_n\_LSB$  are provided from one of the bits included in each upper byte region except the most significant bits.

Figs. 9a through 9b are structural diagrams illustrating the switch array 400, the data I/O buffer 500 and the sense amplifier array 30 of Fig. 1.

The data I/O buffer 500 is connected to an I/O bus. The I/O bus is divided into a lower byte bus  $LB\_BUS$  and an upper byte bus  $UB\_BUS$ . The lower byte bus  $LB\_BUS$  comprises  $m$  bits, and the upper byte bus  $UB\_BUS$  comprises  $n$  bits. The lower byte bus  $LB\_BUS$  is connected to the lower byte region 510 of the data I/O buffer 500. The upper byte bus  $UB\_BUS$  is connected to the upper byte region 520 of the data I/O buffer. Each sense amplifier included in the sense amplifier array 30 is divided into a lower byte region 31 and an upper byte region 32.

The switch array 400 comprises a first switch 410, a second switch 420 and a third switch 430. The first switch 410 connects the lower byte bus  $LB\_BUS$  to the lower byte region 31 of the sense amplifier array 30. The second switch 420 connects

the lower byte bus LB\_BUS to the upper byte region 32 of the sense amplifier array 30. The third switch 430 connects the upper byte bus UB\_BUS to the upper byte region 32 of the sense amplifier array 30. The second switch 420 transmits n bits of sense amplifier bits to the lower byte bus LB\_BUS.

5            Fig. 9b additionally shows control signals in the switch array 400 and the data I/O buffer 500 of Fig. 9a. The lower byte region 510 of the data I/O buffer 500 is controlled by ORing the control signals LB\_EN and Byte\_EN. The on/off operations of the first switch 410 are controlled by a control signal LB\_SW\_EN. The on/off operations of the second switch 420 are controlled by a control signal Byte\_SW\_EN.  
10    The on/off operations of the third switch 430 are controlled by a control signal UB\_SW\_EN.

Fig. 10 is a structural diagram illustrating the switch array 400 of Fig. 9. According to a preferred embodiment of the present invention, the first switch 410, the second switch 420 and the third switch 430 have the same structure. Each switch  
15    comprises a predetermined number of transmission gates arranged in parallel. A transmission gate included in the first switch 410 is controlled by the control signal LB\_SW\_EN. A transmission gate included in the second switch 420 is controlled by the control signal Byte\_SW\_EN. A transmission gate included in the third switch 430 is controlled by the control signal UB\_SW\_EN.

20            Fig. 11 is a structural diagram illustrating the sense amplifier array 30 and a column decoder 200 of Fig. 1. As described above, each sense amplifier in the sense amplifier array 30 is included either in the lower byte region 31 or in the upper byte

region 32. The sense amplifier array is controlled by output signals  $Y<0>\sim Y<n>$  of the column decoder 200.

Figs. 12a through 12b are detailed structural diagrams of the switch controller 300 of Fig. 1. The switch controller 300 receives control signals A\_LSB, /Byte, /LB, /UB, and output signals of the column decoder to provide control signals LB\_SW\_EN, UB\_SW\_EN, Byte\_SW\_EN, LB\_EN and UB\_EN.

Referring to Fig. 12a, the circuit of Fig. 12a generates control signals LB\_EN and UB\_EN provided to the data I/O buffer 500 and control signals Byte\_EN, Byte\_BUF, A\_LSB\_0 and A\_LSB\_1 used in the intermediate process.

The /Byte signal determines activation of the lower byte region. The Byte\_BUF signal is generated by buffering the /Byte signal, and the Byte\_EN signal is generated by inverting the Byte\_BUF signal.

The /LB signal determines activation of lower bytes. The LB\_EN signal is generated by performing an AND operation on ("ANDing") the buffered /LB signal and the Byte\_BUF signal and then by inverting the signal obtained from the AND operation. When the /Byte signal is "low", the Byte\_BUF signal is "low". As a result, the LB\_EN signal becomes "high" regardless of the level of the /LB signal. However, when the /Byte signal is "high", the Byte\_BUF signal is "high". As a result, the level of the LB\_EN signal is regulated by that of the /LB signal.

The /UB signal regulates activation of upper bytes. The UB\_EN signal is generated by ANDing the Byte\_BUF signal and a signal generated by buffering and

then inverting the /UB signal. When the /Byte signal is “low”, the Byte\_BUF signal is “low”. As a result, the UB\_EN signal becomes “low” regardless of the level of the /LB signal. However, when the /Byte signal is “high”, the Byte\_BUF signal is “high”. As a result, the level of the UB\_EN signal is regulated by that of the /UB signal.

5           The A\_LSB signal converts data of upper bytes into data of lower bytes. The A\_LSB\_1 signal is generated by ANDing the A\_LSB signal and the Byte\_EN signal. The A\_LSB\_0 signal is generated by ANDing the A\_LSB signal and the Byte\_EN signal and then inverting the signal obtained by the AND operation. When the /Byte signal is “low”, the Byte\_EN signal is “high”, one of the A\_LSB\_1 or the A\_LSB\_0  
10 signals becomes “high”, and the other signal becomes “low”. However, when the /Byte signal is “high”, the Byte\_EN signal is “low”. As a result, the level of the A\_LSB\_0 signal becomes “high”, and the level of the A\_LSB\_1 signal becomes “low” regardless of the level of the A\_LSB signal.

The circuit of Fig. 12b outputs control signals LB\_SW\_EN, UB\_SW\_EN and  
15 Byte\_SW\_EN by using the signals A\_LSB\_0, A\_LSB\_1, UB\_EN and Byte\_EN of Fig. 12a and the output Y<n> of the column decoder 200.

The control signal LB\_SW\_EN for controlling the on/off operation of the first switch 410 of Fig. 9b is obtained by ANDing the A\_LSB\_0 signal and the output Y<n> of the column decoder 200. The control signal Byte\_SW\_EN for controlling the on/off  
20 operations of the second switch 420 of Fig. 9b is obtained by ANDing the signals A\_LSB\_1 and Byte\_EN and the output Y<n> of the column decoder 200. The control signal UB\_SW\_EN for controlling the on/off operations of the third switch 430 of Fig.

9b is obtained by ANDing the inverted Byte\_EN signal, the UB\_EN signal and the output Y<n> of the column decoder 200. The function of each signal is as follows.

Figs. 13a through 13d are timing diagrams illustrating operations of the switch array 400, the sense amplifier array 30 and the data I/O buffer 500.

5 Fig. 13a shows the timing diagram when the first switch 410 is activated, and data in the lower byte region 31 of the sense amplifier array 30 is provided to the lower byte region 510 of the data I/O buffer 500. In this state, the /Byte signal is inactivated to the "high" level, the /LB signal is activated to the "low" level, and the /UB signal is inactivated to the "high" level. Here, the Byte\_EN signal becomes "low", the  
10 Byte\_BUF signal becomes "high", the LB\_EN signal becomes "high", the UB\_EN signal becomes "low", and the A\_LSB\_0 becomes "high", and the A\_LSB\_1 becomes "low" (see Fig. 12a).

Since the A\_LSB\_0 signal is "high", the LB\_SW\_EN signal becomes "high". Since the UB\_EN signal is "low", the UB\_SW\_EN becomes "low" (see Fig. 12b). As  
15 a result, the upper byte region 520 of the data I/O buffer 500 is inactivated (see Fig. 9b). If the LB\_EN signal becomes "high", a signal obtained by performing an OR operation on ("ORing") the signals LB\_EN and Byte\_EN becomes "high". As a result, the lower byte region 510 of the data I/O buffer 500 is activated (see Fig. 9b). Here, data in the lower byte region 31 of the sense amplifier array 30 is outputted into the lower byte  
20 region 510 of the data I/O buffer 500.

Fig. 13b shows the timing diagram when the third switch 430 is activated, and

data in the lower byte region 32 of the sense amplifier array 30 is provided to the lower byte region 520 of the data I/O buffer 500. In this state, the /Byte signal is inactivated to the “high” level, the /LB signal is inactivated to the “high” level, and the /UB signal is activated to the “low” level. Here, the Byte\_EN signal becomes “low”, the  
5 Byte\_BUF signal becomes “high”, the LB\_EN signal becomes “low”, the UB\_EN signal becomes “high”, and the A\_LSB\_0 becomes “high”, and the A\_LSB\_1 becomes “low” (see Fig. 12a).

Since the A\_LSB\_0 signal is “high”, the LB\_SW\_EN signal becomes “high”. Since the UB\_EN signal is “high”, the UB\_SW\_EN becomes “high” (see Fig. 12b).  
10 As a result, the upper byte region 520 of the data I/O buffer 500 is activated (see Fig. 9b). If the LB\_EN signal becomes “low”, a signal obtained by ORing the signals LB\_EN and Byte\_EN becomes “low”. As a result, the lower byte region 510 of the data I/O buffer 500 is inactivated (see Fig. 9b). Here, data in the upper byte region 32 of the sense amplifier array 30 is outputted into the upper byte region 520 of the data  
15 I/O buffer 500.

Fig. 13c shows the timing diagram when the first switch 410 and the third switch 430 are activated, data in the lower byte region 31 of the sense amplifier array 30 is provided to the lower byte region 510 of the data I/O buffer 500, and data in the upper byte region 32 of the sense amplifier array 30 is outputted into the upper byte region  
20 520 of the data I/O buffer 500. The detailed operation is omitted because it is similar to the above-described operation.

Fig. 13d shows the timing diagram when the first switch 410 and the second

switch 420 are activated in turn. In this state, the /Byte signal is inactivated to the “low” level, and the /LB signal and the /UB signal are inactivated to the “high” level. Here, the Byte\_EN signal becomes “high”, the Byte\_BUF signal becomes “low”, the LB\_EN signal becomes “high”, the UB\_EN signal becomes “low”, and the A\_LSB\_0 becomes a signal obtained by inverting the A\_LSB signal, and the A\_LSB\_1 becomes the same value of the A\_LSB signal (see Fig. 12a).

Since the output Y<n> of the column decoder 200 is activated, the Byte\_EN signal is “high”, the UB\_SW\_EN signal is “low”, the LB\_SW\_EN is at the same level with the A\_LSB\_0, and the Byte\_SW\_EN is at the same level with the A\_LSB\_1. If the A\_LSB signal is “high”, the LB\_SW\_EN becomes “low”, and the Byte\_SW\_EN becomes “high”. If the A\_LSB signal is “low”, the LB\_SW\_EN signal becomes “high”, and the Byte\_SW\_EN signal becomes “low” (see Fig. 12b). As a result, the upper byte region 520 of the data I/O buffer 500 is inactivated, and the lower byte region 510 is activated (see Fig. 9b).

An example is described where data of a memory device is processed by 2 bytes, and data of a system bus is processed by 1 byte. Here, an address of a system bus is designated every 1 byte of data, and an address of a memory device is designated every 2 bytes of data. The number of address bits used in the system should be one more than that used in the memory device. The data bit A\_LSB in the upper byte region is used as an address bit in order to compensate for the insufficient address bit (see Figs. 8a through 8d).

The process of storing data into a memory is as follows. An address of a



system bus is designated every 1 byte of data, and the system bus is provided to the lower byte region 510 of the data I/O buffer 500. Here, if the A\_LSB\_0 signal becomes “high”, the A\_LSB\_1 becomes “high”, the LB\_SW\_EN becomes “low”, and the Byte\_SW\_EN becomes “high”. As a result, the lower byte region 510 of the data I/O buffer 500 becomes connected to the lower byte region 31 of the sense amplifier array 30 via the first switch 410 (see Figs. 9b, 12a and 12b). If the A\_LSB signal becomes “low”, the A\_LSB\_0 signal becomes “high”, the LB\_SW\_EN becomes “high”, and the Byte\_SW\_EN signal becomes “low”. As a result, the lower byte region 510 of the data I/O buffer 500 becomes connected to the upper byte region 32 of the sense amplifier array 30 via the second switch 420.

The process of reading data from the sense amplifier array 30 to the data I/O buffer 500 is performed as described above.

Accordingly, the semiconductor memory device of the present invention does not need extra interfacing devices by effectively changing the data I/O bandwidth of the memory device.

While the present invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and described in detail herein. However, it should be understood that the invention is not limited to the particular forms disclosed. Rather, the invention covers all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined in the appended claims.